JOURNAL OF AGRICULTURAL RESEARCH

VOL. X WASHINGTON, D. C., JULY 9, 1917 NO. 2

A STUDY OF THE RATE OF PASSAGE OF FOOD RESIDUES THROUGH THE STEER AND ITS INFLUENCE ON DIGESTION COEFFICIENTS

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INTRODUCTION

As a result of some earlier investigations conducted at this Station [1] on the association action of feeds, it was found that the digestibility of the crude fiber of some feeds was apparently lowered when these were fed in a ration containing certain other feeds. Our observations also indicated that these influencing feeds caused an increase in the rate of food passage through the steer. A study of the data obtained from these earlier feeding trials suggested that there might be a correlation between the time required for the passage of the food through the animal and the moisture content of the feces.

Studies have been made on this earlier work with attention directed especially to the relationship between the moisture content of the feces and the digestion coefficients; and, in addition, essentially the same digestion experiments have been repeated and similar comparisons made upon these data. An attempt was made to follow more closely and directly by means of rubber markers the time required for passage of the food residues through the steers. Further efforts were made to determine the rate of passage by means of calculations based upon the intake of food and outgo of feces and the alimentary-tract contents as ascertained on slaughtering. Thus, three methods have been employed in studying the rate of passage of food residues and the influence on the digestion coefficients.

I.—MOISTURE CONTENT OF THE FECES

Although an expression for the exact time required for the passage of food residues can not be obtained from the determination of the moisture content of the feces, direct comparisons may be made of the relation

[1] EWING, P. V., AND WELLS, C. A. THE ASSOCIATIVE DIGESTIBILITY OF CORN SILAGE, COTTONSEED MEAL, AND STARCH IN STEER RATIONS. Ga. Agr. Exp. Sta. Bul. 115, p. 269-296, 7 diagr. 1915.

between the moisture content and the coefficients of digestion. Upon the assumption that a high moisture content of the feces accompanies a more rapid rate of passage, comparative values may be obtained for the time of passage. To avoid the complications in the calculations and results which would arise if comparisons were made of the data obtained while on different rations, we have made our studies on the correlations between the high and low moisture contents of the feces and the corresponding digestion coefficients where the same rations were employed. In Table I these results, as obtained from two series of digestion trials, both of which were made in duplicate, are given. Correlations were then made between the digestion coefficients and the moisture content of the feces. Arranged in table form we have the kind of correlation for each ration as indicated in Table I, no sign being used in those instances where contradictory results for the two series were obtained.

TABLE I.—*Correlation between the moisture content of the feces and digestive coefficients*

Ration No.	Composition of ration.			Dry matter.	Ash.	Nitrogen.	Crude fiber.	Nitrogen-free extract.	Fat.
	Silage.	Cotton-seed meal.	Starch.						
	Per cent.	*Per cent.*	*Per cent.*						
1	100.0	0.0	0.0	.....	.....	−	.....	+	.....
2	0.0	100.0	0.0	+	+	.....	.....	+	.....
3	70.0	30.0	0.0	+	+	.....	.....	.....	−
4	50.0	50.0	0.0	+	+	−	+	.....	.....
5	34.5	34.5	31.0	.....	.....	−	+	+	−
6	69.0	0.0	31.0	.....	−	+	+	.....	.....
7	30.0	70.0	0.0	+	+	.....	+	+	.....
8	15.8	36.9	47.3	.....	+	−	.....	−	−

While in the cases of the ash, nitrogen, and nitrogen-free extract the results do not always agree, the indications are that, with a higher moisture content of the feces, there is a more complete digestion of all nutrients except nitrogen and fat. According to Kellner,[1] the occurrence of nitrogenous and ether soluble substances in the feces is attributable largely to metabolic processes, mucus, intestinal epithelium, microorganisms, and especially to the content of the digestive juices, notably the bile. Since a high moisture content of the alimentary tract comes from the copious secretion of the digestive juices, it results naturally that we should have a more complete digestion of most nutrients, with a high moisture content of the feces, and also that the excessive nitrogen-containing and ether-soluble compounds of the feces should indicate a decrease in the digestion of these nutrients.

[1] KELLNER, Oskar. DIE ERNÄHRUNG DER LANDWIRTSCHAFTLICHEN NUTZTIERE . . . Aufl. 6, p. 32. Berlin, 1912.

II.—USE OF RUBBER MARKERS

In order to determine more accurately the influence exerted on the digestion coefficients by the rate of passage of the food residues, it was necessary to develop a method by which we could determine with a fair degree of accuracy the time required for the passage of the food residues through the animal, a problem much more difficult in the case of ruminants than in the case of animals with simple stomachs. So far as the available literature shows, little study has been made on this problem as applied to farm animals. Guernsey and Evvard [1] have done some work along this line with swine at the Iowa station. With swine very good results can be obtained by the use of either bone black, carmine, finely ground charcoal, or of bismuth subnitrate or other bismuth compounds, as indicators by feeding at a specified time and noting the time of their first appearance in the feces as manifested by discoloration. Indicators dependent on change of color in the feces can not be used on ruminants, cattle in particular. In some manner they seem to "wash" ahead of the feed and show an abnormally rapid passage. In order to get a marker applicable to ruminants, we experimented with soft rubber disks cut from heavy rubber tubing. One hundred of these were fed at the beginning of a 10-day digestion trial and a count was made of them as they appeared in the feces. By finding the number that appeared during each 12-hour period we expected to obtain a fairly accurate measure of the time required for the passage of the food residues. The number of rubbers appearing up to 48 or 72 hours after feeding, for example, should represent a measure of the feed fed at the same time as the rubbers which had passed through. Some of the indicators appeared within 12 hours, while others were recovered as late as 60 days following, and still others never came out until the steers were slaughtered.

The above-described plan of feeding markers with the ration was followed out, using the same rations given in Table I. An attempt was made to retard or hasten the passage of the food by feeding 60 or 120 gm. of calcium carbonate or magnesium sulphate so that the variations in time required for passage of the food residue might be more marked even on the same ration. Naturally with the use of such small amounts no great variations would occur either in the time required for passage or the moisture content of the feces. This was observed when either of the two salts was fed. In order to determine what effects the substances would have upon the digestion coefficients, comparisons were made between the coefficients of each of the eight rations when fed with 120 and 60 gm. as against those obtained when none was fed. As well as could be determined, there was very slight variation in the moisture content of the feces; and, with the exception of a lowering of the

[1] GUERNSEY, S. C., AND EVVARD, J. M. THE DIGESTIBILITY OF MAIZE CONSUMED BY SWINE. *In* Biochem. Bul., v. 3, no. 11/12, p. 369-372. 1914.

apparent digestibility of ash, which was observed when calcium carbonate was fed, the variation in the digestion coefficients was not greater than could be accounted for on the basis of the dry-matter content of the feces.

After careful and extensive feeding trials, it was found necessary to abandon the use of rubber markers for determining the time for passage, since the method had proved unreliable in each of the experiments. On some of the rations the rubbers apparently passed through with the feeds, while on other rations they either passed through ahead of the food mass or were retained in the alimentary tract during an abnormally long period. When the particles of the feed resembled the rubbers in size, the markers would pass through with the feeds, but when there were no coarse particles of feed in the ration, as in the case of rations made up of cottonseed meal and starch, the rubber markers were passed in some instances, while in others they were not. Furthermore, on the same rations the extent to which the markers passed through seemed partially dependent on the moisture content of the feces.

III.—SLAUGHTER TESTS

A third method was used, based upon a digestion trial followed by a slaughter test. A measure of the time required for the passage of the residue of the feed was obtained by dividing the food and fecal dry-matter content of the alimentary tract by half the sum of the dry matter ingested and excreted per given unit of time. The inaccuracies of the method, arising from certain metabolic processes, are recognized; but their influence would be no greater on these results than on the digestion coefficients, if as much. The data obtained from the digestion trials are summarized in Tables II, III, IV, and V.

TABLE II.—*Results of the digestion trials*

Steer No.	Date.	Weight of steer.	Percentage of silage and cottonseed meal in ration.		Silage fed daily.	Cottonseed meal fed daily.	Dry matter of feed.	Average dry matter in feces (daily).
			Silage.	Cottonseed meal.				
	1916.	*Kgm.*	*Per cent.*	*Per cent.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*
52.....	May 31	385	40	0	6.848	.....	1.6565	0.8206
49.....	June 3	380	60	0	10.270	.....	2.6340	1.2446
46.....	8	362	40	60	6.848	2.016	3.4730	1.5022
45.....	11	385	60	40	10.270	1.338	3.8400	1.5186
44.....	Apr. 27	395	0	60	.....	2.016	1.8170	.5231
53.....	May 29	358	0	40	.....	1.338	1.2060	.3450

TABLE III.—*Results of slaughter tests*

Steer No.	Gross contents.	Dry matter of contents.	Percentage of dry matter in contents.	Dry matter over 2 mm.	Dry matter under 2 mm.	Percentage of dry matter over 2 mm.	Percentage of dry matter under 2 mm.
	Kgm.	*Kgm.*		*Kgm.*	*Kgm.*		
52	67. 000	6. 490	9. 69	2. 410	4. 080	3. 59	6. 10
49	70. 760	7. 260	10. 26	3. 135	4. 125	4. 43	5. 83
46	64. 714	8. 358	12. 92	2. 930	5. 428	4. 53	8. 39
45	65. 460	8. 382	12. 80	3. 965	4. 417	6. 05	6. 75
44	60. 424	3. 670	6. 07	. 000	3. 670	. 00	6. 07
53	36. 581	2. 269	6. 20	. 000	2. 269	. 00	6. 20

TABLE IV.—*Calculation of time required for food passage*

Steer No.	Daily intake of dry matter.	Daily outgo of dry matter.	Half-intake+half-outgo.	Dry matter of steer contents.	Time required for food passage.
	Kgm.	*Kgm.*	*Kgm.*	*Kgm.*	*Days.*
52	1. 6565	0. 8206	1. 2386	6. 490	5. 24
49	2. 6340	1. 2446	1. 9392	7. 260	3. 75
46	3. 4730	1. 5022	2. 4876	8. 358	3. 36
45	3. 8400	1. 5186	2. 6793	8. 382	3. 13
44	1. 8170	. 5231	1. 1701	3. 670	3. 14
53	1. 2060	. 3450	. 7755	2. 269	2. 92

TABLE V.—*Average digestion coefficients of the nutrients of the several rations as determined by several digestion trials, showing gains or losses in cases of compound rations where the gain or loss results from the combination*

Ration No.	Percentage of silage and cottonseed meal in ration.		Dry matter.	Ash.	Nitrogen.	Crude fiber.	Nitrogen-free extract.	Fat.
	Silage.	Cottonseed meal.						
	Per cent.	*Per cent.*						
1	40	0	50. 45	80. 1	87. 1	75. 0	39. 2	64. 2
2	60	0	52. 74	44. 8	88. 8	70. 4	44. 8	65. 8
3	40	60	56. 78	52. 2	83. 4	44. 3	53. 7	90. 7
Gain or loss			−4. 62	+12. 4	−0. 9	−28. 6	+4. 1	−0. 7
4	60	40	59. 70	59. 7	52. 1	87. 0	60. 2	85. 7
Gain or loss			+1. 10	+21. 1	+0. 6	−14. 6	+10. 7	−1. 7
5	0	60	71. 25	.....	81. 9	61. 0	63. 6	96. 6
6	0	[a] 40	71. 25	.....	81. 9	61. 0	63. 6	96. 6

[a] Coefficients derived from results on this ration are unreliable, so that figures given are those obtained on the higher cottonseed-meal ration.

The primary object of the slaughter test was to obtain the dry-matter content of the alimentary tracts of the steers; but incidentally observations were made upon the size of the particles of food residue in the various organs, from which evidence was obtained corroborating that fur-

nished by the rubber markers and which had indicated that the larger or coarser particles of food required a longer time for passage through the animal than the finer particles.

From the data presented in Table IV we were able to obtain a reliable expression for the average time required for the passage of the food residues through the animal. With the rations used and the quantities fed the time varied from 2.9 to 5.2 days. The two most important factors determining the rate of passage are the nature of the ration and the amount fed. Coarse roughages seem to require a considerably greater time than the more finely ground concentrated feeds, this holding true even when the two kinds of feeds are consumed together, as has been shown in a previous publication.[1] As to the influence of quantity, it appears that, when the coarse feeds were fed, a smaller quantity required a greater time for passage of the residues; but, when the feed was a concentrate in pulverized form, the variation was not so pronounced. Of these two factors the nature of the food seems to be of the greater importance in influencing the rate of passage of the residues through the steer.

A valuable study might have been made between the rate of passage as ascertained by means of the slaughter tests and the moisture contents of the feces. Such a comparison is not of value with the rations used, since varying quantities of foods were used, and the effect produced on the moisture content of the feces by the quantity of food consumed has not yet been determined.

In dealing with the influence which the rate of passage of the feed residue may have had on the digestion coefficients we are unable definitely to attribute changes to the rate of passage; and at best it can only be said that associated with the more rapid passage there occurred an apparent gain in the digestibility of the ash, negligible results in the case of nitrogen, a decided loss in the digestibility of the crude fiber, a gain in the case of the nitrogen-free extract, and negligible results in the case of fat. The loss in digestibility of crude fiber was sufficient to overbalance the gains made by the other nutrients, and resulted in a slight decrease in digestibility of total dry matter, with a more rapid passage. These findings do not agree entirely with results obtained when the comparisons were made between the digestion coefficients and the moisture content of the feces, the greatest variation being in the case of the crude fiber. Although a gain in crude-fiber digestion was indicated when the moisture content of the feces was high, a loss was indicated under the third method, where there is a direct measure of the rate of food passage. Crude-fiber digestion is largely a biochemical digestion in which the time element is of importance, and it seems more tenable to assume that we have a less complete digestion of crude fiber if the time of digestion is shortened by a more

[1] EWING, P. V., WELLS, C. A., and SMITH, F. H. THE ASSOCIATIVE DIGESTIBILITY OF CORN SILAGE AND COTTONSEED MEAL IN STEER RATIONS. PART 2. Ga. Agr. Exp. Sta. Bul. 125, p. 149–164, illus. 1917.

rapid passage of the crude fiber through the animal. While Table V indicates no change in the digestion of nitrogen and fat, it should be pointed out that the actual digestion of these nutrients was probably increased by the more rapid movement through the animal. This increase was probably counterbalanced by the metabolic nitrogen and fat residues accompanying the greater flow of digestive juices when the passage of the food residue was more rapid.

DISCUSSION OF RESULTS

The differences attending the accurate measurement of the time required for the passage of food residues has retarded studies along this line although the question is one of considerable importance. In the work reported here only the last method can be considered as offering direct results, although the two other methods were of value. From the standpoint of the specific problem the weakness of the first method is in that it still remains to be proved definitely that the rate of passage of feed residue through the steer can be measured by the moisture content of the feces. Our work has shown that, if a high moisture content of the feces is indicative of rapid passage, then the apparent digestion is more complete probably for all the nutrients with the more rapid passage and less complete with the slower movement. Unfortunately the method of study shows only the relationship and not the extent of the variation in digestion associated with a high moisture content. These results are in accord, however, with cattle-feeding practice, in that cattle are not considered as doing best or making the most of their food unless the feces has a certain semiliquid consistency and has a strong odor of bile. Practical feeders have long realized the advantage of feeding some slightly laxative feeds at all times if the best results are to be secured from the feeding.

In making a closer examination of Table I and the results given there it is interesting and probably of significance to note that the variation, or contradictory results obtained (indicated in the table by the omission of the positive or negative sign), occurred with those rations that might be considered as abnormal. One of these rations contained 31 per cent of cornstarch and 69 per cent of silage, while the other contained 47.3 per cent of starch.

In the case of the second method, which proved impractical for the main object sought, the experiments showed that some solid particles of the feed might remain in the steer as long as 60 days, or even longer. The slaughter tests made later showed that hard particles of feed and foreign substances were especially prone to become delayed in transit either in the reticulum, in the fourth, or true, stomach, or in the first few ventral folds of the duodenum. The coarse feeds and roughages retard the rate of passage of feed residues, a point proved conclusively by the slaughter tests.

It was only by means of the slaughter test that we were enabled to arrive at an accurate measure of the specific time required for the passage of a certain ration residue through the steer. As already stated, the residue from any given feeding may require for its complete expulsion several weeks, or even months. The figures obtained express the average time required for passage, the calculation being based upon the dry matter of the feeds, the content of the digestive organs, and the resultant feces. Expressed as a formula:

$$\text{Time} = \frac{\text{Amount}}{\text{Rate}}, \text{ or } T = \frac{C}{\frac{R+F}{2}}$$

in which T represents time units required for passage of food residue, C the dry-matter contents of the alimentary tract of the steer as determined at the time of slaughter, R the dry-matter content of the ration per given unit of time, and F the dry-matter content or the feces voided for the given unit of time.

In making use of this formula it is recognized that certain end products of digestion, such as residues from digestive juices, cell destruction, and bacterial life, may interfere with the accuracy of the method; but the interference can be no greater than in the case of the determination of digestion coefficients, which are influenced by the same factors when the usual method of determination is employed.

Among other things the greater length of time required for the passage of food residues in the case of the coarser feed was noticeable. Likewise, where the ration or feed is the same, a greater time will be required for the passage of residue from the smaller quantity. In the cases of the two compounded rations, which might be classed as normal rations, the rate of passage of feed residues did not vary a great deal and were between 72 and 84 hours, which might be taken as the average time required for the passage of feed residues through steers on normal rations. The third method of study shows that it is quite probable that, associated with a more rapid passage of feed residue, we have a more complete digestion of all nutrients except crude fiber. Therefore, in actual feeding practice it is desirable that a rapid passage of feed residues be encouraged, since any loss in crude-fiber digestion may be a net gain in energy units on account of the high cost in energy for the digestion of this nutrient.

CONCLUSIONS

(1) In general, a more complete digestion is associated with a more rapid passage of feed residue through the steer.

(2) Crude-fiber digestion seems to be decreased with a more rapid passage of feed residues.

(3) Coarse feeds and roughages retard the rate of passage of residues.

(4) Finer particles of feeds and finer ground feeds pass through the animal more rapidly than the coarser ones.

(5) An increase in the quantity of feed consumed causes an increase in the rate of passage of feed residue.

(6) The greater the capacity of the alimentary tract of the animal the longer the time required for the passage of feed residues.

(7) The determination of the rate of passage of feed residues through steers by means of feces markers or color indicators is not feasible.

(8) Doses of calcium carbonate and magnesium sulphate in quantities of 60 or 120 gm. per steer daily exerted no appreciable influence on digestive coefficients.

(9) The average specific time required for the passage of the feed residues on a normal ration probably varies between 72 and 84 hours.

(10) The rate of passage of feed residue is influenced largely by the nature of the ration and by the quantity, the importance of the two influencing factors being in the order named.

A FURTHER CONTRIBUTION TO THE STUDY OF ERIOSOMA PYRICOLA, THE WOOLLY PEAR APHIS

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In the present paper, in which the complete life cycle of *Eriosoma pyricola* is given, it seems best to discuss somewhat fully the history of the different species recorded on pear roots (*Pyrus communis*). This is especially urgent since complete life studies of the woolly pear aphis have shown that the spring forms as present on elms are remarkably different from the fall forms upon pear roots; in fact, one of the chief characters used in the separation of the species does not exist in the spring forms at all. This is remarkable in view of the fact that this same character, the wax pores, has been the chief one in linking the different forms of other species closely related to the root aphis of the pear.

SYSTEMATIC DISCUSSION

In 1849 Westwood (10)[1] described and figured the work of an aphid on Nelis d'Hiver pear. This injury consisted of knotty growths and swellings on the branches very similar to those produced by the woolly apple aphis, *Eriosoma lanigerum* (Hausmann). A short description and figures of the insect were given with the statement that the species "may be called *Eriosoma pyri*." The woolly apple aphis is known commonly to affect pear trees above ground, while the woolly pear aphis is met only upon the roots. It seems extremely probable, therefore, that the form described by Westwood was none other than the common woolly apple aphis. This, however, the writers have been unable to prove definitely.

In 1851 Fitch (4) described an aphid from apple roots under the name "*Eriosoma pyri*." The author stated that this species formed galls upon the roots. Since the work which Fitch credited to his *E. pyri* was very similar to that of the woolly apple aphis, if indeed not the work of that species, Fitch's *E. pyri* was later considered to be the same as *E. lanigerum* (Hausmann). A large aphid, a species of Prociphilus, occurs upon the apple in the Eastern States, and is not uncommonly found upon the pear, the fall migrants and sexes being usually seen upon those trees. The senior writer (1) has shown, from an examination of Fitch's types, that this form is the one described by Fitch as *E. pyri*. In this paper by the senior writer the species is redescribed as *Prociphilus pyri* (Fitch). The description of the earlier form by Westwood (10), how-

[1] Reference is made by number to "Literature cited," pp. 73-74.

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ever, makes Fitch's name, since a homonym, unavailable. The writers therefore propose the name "*Prociphilus fitchii*" for this species.

Another species of the same genus, *P. corrugatans* (Sirrine), occurs upon pear foliage, causing the leaves to curl. All of these species, however, are quite different from the woolly pear aphis.

Goethe, in 1884, (5) described a form occurring upon pear roots which he considered to be a variety of the woolly apple aphis, *Eriosoma lanigerum*. He called it by the varietal name of *pyri* and stated that it lives upon pear roots throughout the year. In the fall, according to this author, winged forms are produced which fly to the underside of the leaves in order to deposit the sexes. The female after fertilization lays one egg upon the pear tree. No further observations were made into the life history, so far as the forms from the egg are concerned.

Mordwilko, in 1901 (7), stated that he had examined the form from pear roots described as *E. pyri* by Goethe, and was convinced that it could not be considered as a variety of *E. lanigerum*, but must be treated as a good and distinct species. He therefore elevated the *pyri* of Goethe to specific rank, and this name has been commonly used by European workers for the root aphis which attacks pears.

In 1841 Hartig (6) described a species of aphid found producing sac-like galls on elm trees under the name of *E. lanuginosa*. This species has been redescribed and figured by several European students and its work has become well known in the European countries of the continent, as well as in the British Isles. It would seem from the statements of Tullgren (9) that the species does not occur in the Scandinavian peninsula. In America Patch (8) has figured a gall from Connecticut which was doubtfully referred to this species. No specimens were secured at the time, and no positive record, therefore, was made.

In Europe, where the life of *E. lanuginosa* on the elm (*Ulmus* spp.) has been followed, its biology has been well understood and carefully studied. Some of the earlier writers held incorrect views in regard to the sexes and hibernation of the species, but later studies have cleared up its entire life history.

In 1914 Börner (3), acting upon the suggestion of Mordwilko, showed that the *E. pyri* of Goethe is the alternate form of *E. lanuginosa* Hartig. His experiments were made near Metz. Only a few galls were located, and the insects from these were transferred to pear trees in pots. In July two small colonies were present on the roots of the potted plants, and the insects of these colonies were the offspring of the winged forms of *E. lanuginosa*. It was thus definitely established that the European pear-root aphis, *Eriosoma pyri* Goethe, is the alternate form of the elm species *Eriosoma lanuginosa* (Hartig).

The present writers (2) have described, under the name *E. pyricola*, the American woolly pear aphis, which had before that time been thought to be the woolly apple aphis. This was done because the form did not

agree in structure with any of the known species, including *E. lanuginosa* Hartig. It was pointed out, however, that the woolly pear aphis was very close in general structure to European specimens of *E. lanuginosa*. This was shown in the following words (2, p. 358):

> The winged forms of *E. pyricola* are remarkably like those of *E. lanuginosa* Hartig. The proportions are almost exactly the same.

The marked difference in the wax pores and minor differences in the sensoria were considered as showing a very distinct species. The present studies have shown that these characters are not the same in the spring forms living on elms as in the summer and fall forms living on pear roots, but that in the spring forms they are very similar to those of *E. lanuginosa*. From the fact that in other species of Eriosoma the wax pores are constant the writers concluded that they would be constant also in the *E. pyricola* and in *E. lanuginosa*. They are not so in *E. pyricola*. Lack of fall material of *E. lanuginosa* makes it impossible to determine whether they are constant in that species or not. From the very great similarity between the spring forms of *E. pyricola* and *E. lanuginosa* the writers are led to believe that the same variation will be found between the spring and fall forms of *E. lanuginosa*. If this proves true, there will no longer be any reason for keeping the two species distinct and *E. pyricola* will become a synonym of *E. lanuginosa*.

If this supposition is correct, and it is all but proved, it will show without a doubt the following to be facts:

(1) The destructive woolly pear aphis of this country is a European insect imported into the Western States on pear stock.

(2) It has spread rapidly in the West in the last 25 years and now occurs from Washington to California, although as yet it is most destructively abundant in California.

(3) The isolated infestations in the Middle West and in the East are due to separate infested importations.

(4) While the alternate winter forms thrive best on European elms, the species is able to live successfully upon the common American elm and at no very distant date may become entirely adapted to this native tree.

(5) The species is liable through importations to gain a foothold in any pear-growing region, for, as recently as 1916, skins have been collected on seedling nursery stock.

DESCRIPTION OF ERIOSOMA PYRICOLA

STEM MOTHER.—Antennal segments with the following measurements: I, 0.048 mm.; II, 0.064 mm.; III, 0.208 mm.; IV, 0.112 mm.; V, 0.05 mm. Segment IV of antenna fully imbricated and armed with rather prominent hairs. Segment V fits close against segment IV, with little constriction, so that it does not give the general appearance of a distinct segment, although this is easily observable when looked for. The unguis comprises somewhat more than half of the segment. Form of body globose. Length

from vertex to cauda, 2.24 mm; legs short, the tibiæ being about equal in length to the antennæ.

SPRING MIGRANT.—Varies considerably in size, but the following measurements represent about the average. Antennal segments: I, 0.064 mm.; II, 0.064 mm.; III, 0.448 mm.; IV, 0.144 mm.; V, 0.1 mm.; VI, 0.08 mm. Segment III of antenna, with 25 to 30 annular sensoria on the lower surface of the segment and almost encircling it; segment IV with 7 or 8 and segment V with 5 or 6. Segment VI usually without sensoria except the permanent ones. Forewing about 2.5 mm. long and 0.96 mm. broad. Hind tibia, 0.738 mm.; hind tarsus, 0.144 mm. Legs slender.

In comparing the spring migrants of *E. pyricola* and *E. lanuginosa* some differences are encountered. These are principally in the antennæ and are shown in the accompanying illustrations, reproduced from photographs. It will be noted that the antennæ of *E. lanuginosa* (Pl. 9, *A*) are considerably heavier than those of *E. pyricola* (Pl. 9, *B*, *E*). Segments IV and V seem also to be comparatively larger and armed with more and heavier sensoria. Segment VI, as compared with V, is somewhat shorter in *E. lanuginosa* than in *E. pyricola*. There are available for study, however, only a few specimens of *E. lanuginosa*. It seems quite probable that these represent only variations in the species and that, when a long series of *E. lanuginosa* is available, specimens will be found similar to the American forms.

Specimens of fall migrants upon European pear stock (Pl. 9, *C*) are without doubt the same species as that occurring in America (Pl. 9, *D*). It is possible that these specimens are in reality the fall migrants of *E. lanuginosa*. This can be proved only by a study of reared European material, which, under present conditions, it is impossible to obtain.

DEVELOPMENT OF THE GALLS AND GALL APHIDS

In a former article (2) it has been mentioned by the writers that the fall sexuparous migrants leave the pear roots upon which they have developed and fly to elm trees to deposit the sexes on the trunks and limbs. These migrants settle on *Ulmus americana* and *U. campestris*. The latter tree is distinctly preferred; in fact, no perfect galls have been produced on the former. The sexed female after mating deposits a single egg in a crack in the bark or underneath a bud scale.

The eggs during the winter are reddish, greenish red, or greenish brown, but immediately before hatching appear grayish brown, due to the color of the embryo. The empty shell is dirty white.

From this egg hatches the young stem mother which ascends a trunk or limb and seeks an expanding leaf. In 1916 hatching commenced March 23 and extended until April 18, the majority hatching during the first two weeks of April.

The newly hatched stem mother is oval in shape, bare and shining, of a yellowish or brownish olive hue with small black eyes and hyalin appendages and beak. The thoracic region is lighter in color than the

rest of the body and the segmentation is well marked. The beak reaches about to the third abdominal segment.

This form settles on the underside of an elm leaf near the midrib and generally not far from the base. After the young aphid has fed for a very few days, the leaf begins to curl around it and the curling and twisting become more pronounced as the insect grows, so that by the time it has reached the third instar the leaf in the form of a gall has completely closed around it. This gall is a part of the leaf tissue, ribs, and parenchyma, which has developed independently of the remainder, owing to the puncture and feeding of the insect. The walls of the gall are thicker than the normal tissue, and frequently the petiole is abnormally thickened. Galls harboring immature stem mothers have the form of a compact spiral twist. On the outside they bear a thick fringe of whitish pile, and in color they vary from the normal leaf color to a pale yellowish white, often rosy tinted when exposed to much direct sunlight. Many occur which harbor more than one fundatrix, but even those with single tenants vary noticeably in size. The average diameter of galls containing third-instar fundatrices was ¼ inch.

The young stem mothers in the first instar are greenish gray with grayish "meal" on dorsum and pleura; they are elongate oval. In succeeding instars the color is slaty blue, and considerable fine whitish "wool" issues from pores; the shape becomes short pyriform, and globules of viscous honeydew are ejected from the anus.

The mature fundatrix is dark bluish green, robust, clothed with white wooly and waxy filaments, the larger of which arise from four longitudinal dorsal and dorso-lateral rows of pores; the antennæ and legs are yellowish brown; the tarsi, knees, and two distal antennal segments are dusky gray; the beak is very short, yellowish brown, with a gray tip; the dorsum of the head is gray; the eyes are black, simple, and very small; the body is globular oval, becoming greatly distended with age. Recently matured stem mothers were collected between May 17 and 23, and it was observed that several matured between these dates. Field observations indicate that this was the period in which the majority reached the adult stage. It appeared that the stem mothers fed from four to five weeks in the immature stages. The galls containing the mature fundatrices varied in diameter from ⅓ to ½ inch, and their shape was a rather short subglobular spiral. Figures *A* and *D* of Plate 10 show a gall, collected on May 13, which harbored a fourth-instar fundatrix.

Following upon the maturing of the stem mother the galls grow very rapidly and change their shape to the form depicted in Plate 10, *B*, *C*. The photographs from which these illustrations were made were taken on July 12 and present two diametrically opposite views of the same gall, which contained several hundred inmates. It should be observed that the gall is no longer closed.

At the end of May the galls were as large as ⅞ inch in diameter on large leaves, whereas those on naturally small leaves were mostly under ½ inch. During June the galls developed rapidly, assuming an oblong saclike or baglike appearance, the portions of leaf between the lateral ribs became much distended, and the ribs thickened abnormally. The external color varied from pale yellowish white to purplish brown, the majority of the galls exposed to sunlight being rosy and those in shady places light green or yellow with purplish blotches. Toward the end of June (June 21) the galls averaged 1⅛ by 1¼ inches, and specimens as large as 2¾ by 1¾ inches were observed on unusually large leaves.

By July 8 the largest specimens measured 4 by 2½ inches, the smallest did not exceed ¼ inch maximum diameter, and the average size was about 1¼ by 1⅓ inches—a slight increase in size over that existing on June 21. By the first week in July the galls have attained their full size; and, soon after having been forsaken by their inmates, they turn brown all over and become brittle but remain attached to the twigs in large numbers all through the winter succeeding (Pl. 10, *E*).

Mature galls frequently comprised the whole of a leaf, as in Plate 10, *B* and *C*, while in other instances only one side of the midrib is affected. Less frequently two or more separate galls occurred on the same leaf, and galls were more usually found on leaves at the base of the year's growth because the young stem mothers on most trees hatched at the time when the first leaves of the spring growth were unfolding, and settled on the earliest leaves. The twig illustrated in Plate 10, *B* and *C*, is an exception and occurred on a tree which threw out much of its foliage before the stem mothers hatched.

The mature fundatrix deposits young prolifically, and her body rapidly swells. Four individuals under observation deposited each about 75 young in three weeks, when the eldest matured as second-generation wingless forms (fundatrigenia). No definite records were obtained of the total progeny of the stem mothers, but it appears that they may deposit as many as 300 young during the four or five weeks in which they are alive in the adult state. It should be remarked that galls have been collected in July which contained upwards of 1,000 larvæ and pupæ, but it could not be ascertained whether these were the progeny of a single fundatrix, of several fundatrices, or the combined progeny of fundatrices and wingless viviparous females of other generations.

The newly hatched progeny of the stem mother are pink or light carmine, and elongate; the dorsum of the head is gray; the eyes are red; the thorax is light hyalin yellowish pink; the appendages and beak are hyalin whitish; the leg joints are narrowly dusky gray; the tarsi and tip of the beak are dusky gray. The larvæ remain pink during their early growth and are deeper in color after molting. During the last two immature instars the body darkens and assumes a pyriform color, but the pupæ are elongate.

The mature wingless female of the second generation is oval, dark bluish black, the body clothed with short white waxy threads (longest at the caudal extremity) and pruinose "meal" of the same color; the cornicles are black and very short; the antennæ are one-third the body in length; the antennæ and legs are bluish gray with a lilac tint, although at first pale orange; the tibæ and base of the femora are paler than the rest of legs.

The wingless forms mature in about three weeks inside the gall. In 1916 they were not at all common, as will be seen from the records which follow. They are the earliest progeny of the stem mother and apparently deposit young destined to acquire wings, as no third-generation wingless forms were ever found. Isolated individuals, when placed in empty galls, failed to deposit young or to remain where placed for more than a very few days. At the time the first wingless forms matured, pupæ occurred in the galls, and the latter must have been direct progeny of the stem mothers.

To indicate the scarcity of these second-generation wingless forms, a few observations may be cited:

On June 6 two galls were selected at random for examination of the inmates. One contained, besides the fundatrix, 6 adult wingless forms, 29 pupæ, and 250 larvæ; a second contained, besides 3 fundatrices, 31 adult wingless forms, 71 pupæ, and 531 larvæ. On July 24 a gall contained 6 dead wingless forms, 6 dead pupæ, and 63 pupal skins. During the next two weeks 3 other galls were examined without any trace of second-generation wingless forms being discovered. It might also be said that among the larvæ found in the first two galls there were very few individuals of the size and shape of a wingless form of the fourth instar. The possibility of the second generation's wingless forms leaving the parent gall and founding new galls should not be overlooked; yet the observations made indicate either that no such movement exists or that it is uncommon. Every gall examined about a month after the stem mother matured contained a small number of these wingless second generation individuals, but their production appeared to be limited to just a few of her earliest progeny.

The pupæ of the spring migrant are at first pink, and, when ready to transform, lilac, with the thoracic region suffused with light yellow. The appendages are light amber, and the wing pads pale yellowish white. They are clothed with woolly and waxy filaments, the latter arising from four longitudinal rows of dorsal and dorsolateral pores. The pupæ transform within the gall into winged parthenogenetic forms.

The spring migrants newly transformed are rich brown and soon change to their permanent dark greenish or brownish black color. The shape is elongate, and the body is shining. The general resemblance to the fall migrant is very marked. The head and thorax are shining black; the prothorax and abdomen vary from deep lilac to dark green,

rarely mottled with orange; the abdomen bears a certain amount of bluish white pubescence, and on the caudal segment is a tuft of short white "wool"; the cornicles are black, very short; the antennæ are a little over one-third the length of the body, dark greenish or yellowish brown, joints III to VI bearing transverse sensoria; the legs are light orange, the apical third to half of the femora is dark brown, the base and apex of the tibæ and the tarsi are light gray; the beak is pale yellow at base, elsewhere dark grayish brown, reaching the second coxæ; the stigma is a grayish green.

In 1916 the earliest spring migrants transformed in advanced galls exposed to maximum sunlight as early as June 8. On a young, partially shaded cork elm in the laboratory premises at Walnut Creek, Cal., the first migrants transformed on June 16, after a growing period of about 24 days. By the fourth week in June nearly every gall examined contained winged forms, and by July 10 large numbers of the earlier galls had been forsaken, all the inmates destined to acquire wings having transformed and flown off. By the end of July hardly a gall with living inmates could be found. Between June 19 and July 24, records were kept of the migrant production in three galls confined with cheesecloth on a small cork elm. Respectively, 114, 107, and 76 winged individuals issued from them; in the first case the last migrant developed on July 15, in the second on July 21, and in the third on July 24. These galls were under the average size, and, moreover, at least as many larvæ as persisted forsook the galls, probably as a result of the handling to which they were subjected. On July 17 a gall infestation, mostly on large leaves, was examined, and over a thousand pupæ and larvæ were estimated to be inhabiting the larger galls of from 2½ to 3½ inches maximum diameter. To judge by the total counts made, it is probably not an exaggeration to say that the gall of average size produced in 1916 at least 400 winged forms (migrants), and, as a heavily infested elm tree may contain as many as 400 galls, the enormous number of spring migrants produced can be imagined. Great numbers, however, were caught in spider webs on the elms; many others, including pupæ, became "choked" through the honeydew deposits within the galls, while the larvæ and pupæ suffered considerable loss in numbers through predatory insects which were able to gain admittance to the interior of the galls after the middle of June. Among these predators adults of *Scymnus* spp. (Coccinellidae) and chrysopid larvæ were most notable and abundant.

Spring migrants were observed resting on pear foliage and actively crawling up and down the lower part of pear trunks. Young deposited by them were taken in spider webs at the base of pear trees, and it appears that the young are normally deposited on pear trunks at or near to the soil surface. Spring migrants when placed in petri dishes with pieces of pear roots on wet sand deposited young which readily settled and fed upon the roots and which precisely resembled in structure—albeit

they were somewhat darker in color—the newly born larvæ of the pear-root aphis.

In confinement it was found that 12 spring migrants deposited an average complement of 22 young with a range of from 10 to 39. These were in every case deposited within three days, and in most cases within 24 hours of transforming

Root-feeding generations were bred in the laboratory at Walnut Creek, Cal., from the wingless progeny of the spring migrants, and in due course the third and fourth generations yielded a large percentage of fall migrants. These fall sexuparous migrants were bred contemporaneously with others which came from a root-feeding strain originally started in 1915.

It may be said that the young deposited by the spring migrants readily fed on pear stocks of Kieffer, French, and Japanese varieties, but, like the root-dwelling larvæ, absolutely refused to feed upon apple roots and fed only in very rare instances upon roots of the quince.

The readiness exhibited by the migrant progeny to settle on pear roots was taken advantage of in colonizing a series of young orchard trees for the purpose of later insecticide tests, and elm galls containing migrants and pupæ were buried near the roots in the soil with the result that in 75 per cent of the trees root infestation speedily resulted. This was found to be a much handier method of general colonization than the use of pieces of infested roots or the application of individuals by brush.

A diagram of the complete life cycle of *E. pyricola* is given in figure 1.

FIG. 1.—Diagram showing the life cycle of *Eriosoma pyricola*.

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PLATE 9

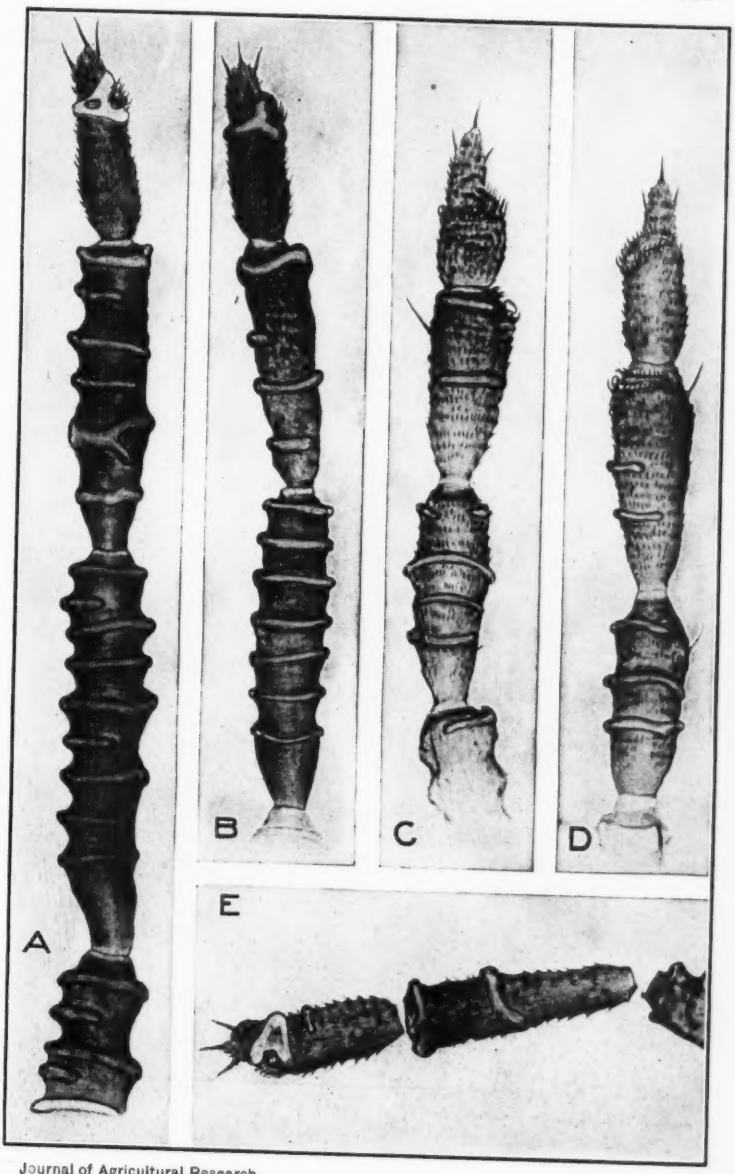
A.—*Eriosoma lanuginosa:* Distal segments of antenna of spring migrant.

B.—*Eriosoma pyricola:* Distal segments of antenna of spring migrant.

C.—*Eriosoma pyricola:* Distal segments of antenna of fall migrant from European pear stock.

D.—*Eriosoma pyricola:* Distal segments of antenna of fall migrant, American material.

E.—*Eriosoma pyricola:* Distal segments of antenna of spring migrant.


A
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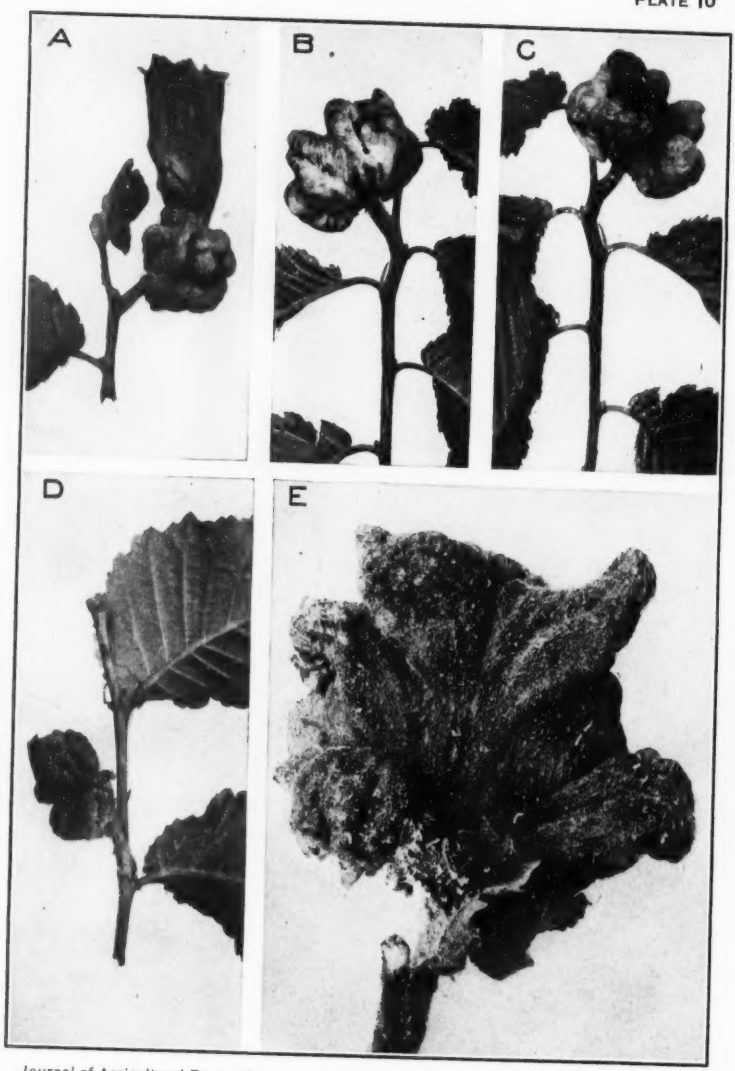
A
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PLATE 10

Eriosoma pyricola:

A, D.—Galls containing fourth-instar stem mothers.
B, C.—Mature galls.
E.—Old gall, slightly enlarged.

MICROORGANISMS AND HEAT PRODUCTION IN SILAGE FERMENTATION

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INTRODUCTION

Heat formation is characteristic of silage fermentation. The amount of heat liberated varies as affected by different factors. The average temperature limits of fermenting forage in the center of the silo range between 30° and 40° C. This represents the temperature of normal fermenting silage. There is a marked difference in the degree of heat noted between the fermenting forage at the top and center of the silo. The amount of oxygen present governs to a large extent the amount of heat formed. More oxygen is present in the surface forage than in the center of the silo, which accounts for the higher temperature at the top of the silo.

In European countries silage is referred to as sweet or sour silage, the amount of heat produced governing the type of fermentation. Sweet silage results when the temperature rises to 50° C., while sour silage is formed if the temperature does not exceed 40° C.

PREVIOUS INVESTIGATIONS

Heat production in fermenting forage has never been satisfactorily explained. While it can not be interpreted from previous investigations that this heating results from the major fermentation processes in silage, it seems highly probable. Investigators differ widely regarding the causative agents concerned in silage ripening. Their conclusions may be briefly summarized as follows: Fermentation processes in silage are due to—

(1) Intramolecular respiration of the tissue cells.

(2) Intramolecular respiration of the tissue cells, and microorganisms. The former action is essential, while the latter is of secondary importance.

(3) Microorganisms.

Fry (7)[1] and Babcock and Russell (1, 2, 3) support the first hypothesis, contending that heat production results from the activity of the plant cells. Russell (12), Kayser (10, p. 367–390), and Samarani (13) state that intramolecular respiration is the most important, but that certain bacilli exert a secondary action. Wollny (15, p. 444–460) likewise believes that heat production is caused by the activity of the plant cells, but that the lactic and acetic acids formed are from the action of bacteria.

[1] Reference is made by number to "Literature cited, pp. 82–83.

Journal of Agricultural Research, Washington, D. C.
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Vol. X, No. 2
July 9, 1917
Key No. Kans.—7

Esten and Mason (6) conclude that microorganisms are the predominating factor in silage ripening, but that heat formation is the result of the activity of plant cells. On the other hand, Burrill (4) states that the high temperature attained in his investigations was caused by two or more species of rodlike bacteria to which butyric-acid production could be attributed. Lafar (11, p. 199–203) and Conn (5, p. 112–114) discuss heat production in silage as the result of bacterial action. Griffiths (8) describes several groups of bacteria, important in silage fermentation, but makes no statement regarding silage heating. In a recent article Hunter and Bushnell (9) show that microorganisms are the essential cause of silage ripening. Sherman (14) suggests the probable importance of acid-producing bacilli in the curing of corn silage.

Evidence is sufficient to warrant the assumption that microorganisms are the influential factor in forage fermentation. It is logical to assume, therefore, that the heating of ripening forage is a result of their activities. With this hypothesis in mind the following investigations were planned.

METHOD OF PROCEDURE

Alfalfa, corn, cane, and kafir forage, siloed under laboratory conditions, were used for silage production. The forage was finely cut and packed tightly in 1-quart thermos fruit jars and hermetically sealed. Thermos jars were used in order to prevent as much heat radiation as possible. Care was taken each time to entirely fill the jars before sealing, as such air spaces would afford opportunity for the growth of molds. The heat thus liberated by their activities would offer a source of error in the interpretation of results. In order to bring heat radiation to a minimum, the thermos bottles were kept at a fairly uniform temperature. In a majority of the experiments this temperature ranged between 35° to 37° C. In a few cases, however, they were kept near 20°. The general course of action was the same in each case.

The temperature readings were determined by the use of thermometers and thermo-resistance coils. A type of thermometer was used which allowed the extended mercury end of the thermometer to be inserted to the center of the jar, while the graduations remained above the neck of the bottle. It was graduated to 0.1° C.

The resistance coil consisted of 40 feet of black-enameled magnet wire No. 36, wound around a small-sized spool. A thin coat of paraffin covered the coil in order to insure perfect insulation. The wire leads connecting the coil and resistance box were incased in small glass tubing from the coil to the outside of the thermos jar. This was to avoid breaking the threadlike wires, especially during the filling of the jars. Each was standardized with a thermometer and the resistance readings converted into degrees. The coils also registered to 0.1° C. All thermometers and resistance coils were standardized against each other, and the necessary temperature corrections noted.

The general plan of procedure for determining the relative importance of microorganisms and intramolecular respiration of the plant cells in the heating of siloed forage provided checks of different types on microbial activity. Heat production was observed in—

(*a*) Normal fermenting forage;
(*b*) Forage treated with a weak antiseptic;
(*c*) Forage treated with heat;
(*d*) Heated forage inoculated with bacteria;
(*e*) Cured or dried forage.

Normal fermentation, used as a check, was provided by siloing the untreated forage. When alfalfa was used, 2 to 5 per cent of cane sugar was added to supply an available source of carbohydrate for the ferments.

Forage treated with a weak antiseptic offered favorable conditions for intramolecular respiration of its tissue cells, while the action of the microbial flora was checked. Two to three per cent of chloroform was used for this purpose.

The action of both microorganisms and tissue enzyms was prevented by heating the forage for one to two hours at 100° C. In this way all plant enzyms and the majority of the essential microorganisms were killed. Forage thus made inert was treated with chloroform to check the action of any organisms not killed by the heat and those which entered during the siloing of the heated forage. Such treated forage was used chiefly as a control both for heat production and chemical changes.

Heated forage was also inoculated with a pure culture of the Bulgarian-like organism isolated from silage.

Cured and dried forage, to which the proper amount of moisture had been added to insure conditions for fermentation, was likewise siloed. Owing to the destruction of large quantities of plant enzyms by drying, such forage offered little or no opportunity for tissue activity.

Total acidity determinations were made by the method described by Hunter and Bushnell (9). The results are expressed in terms of lactic acid per gram of dry forage.

EXPERIMENTAL DATA

Only representative records of the different kinds of forage are reported from the large amount accumulated, as all exhibited the same essential characteristics. The temperature readings in each case are plotted as curves. Figures 1 to 10, inclusive, indicate the heat-producing ability of the different kinds of forage. The untreated and inoculated forage all exhibited a marked increase in acid production, while the chloroformed and heated samples exhibited no increase.

Good clean-flavored silage resulted in every instance from the fermentation of the untreated, green, cured, and inoculated forage. The treated

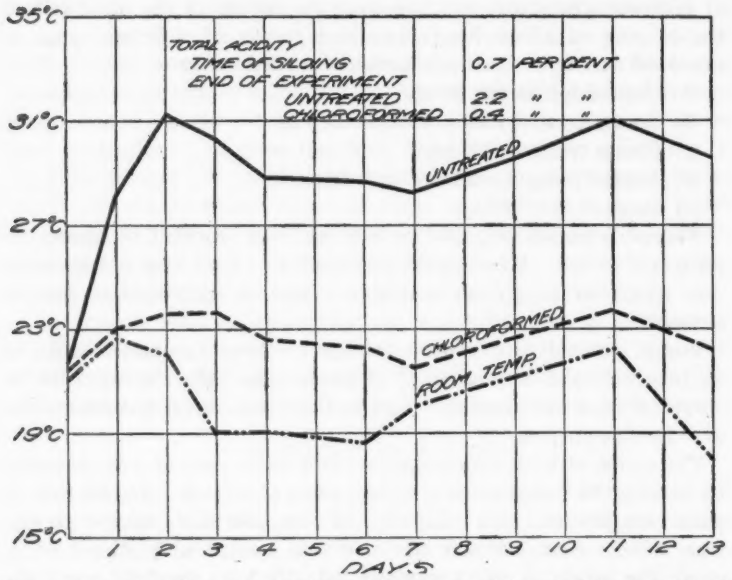

FIG. 1.—Curves representing the heat-producing ability of cured alfalfa, untreated and treated with chloroform.

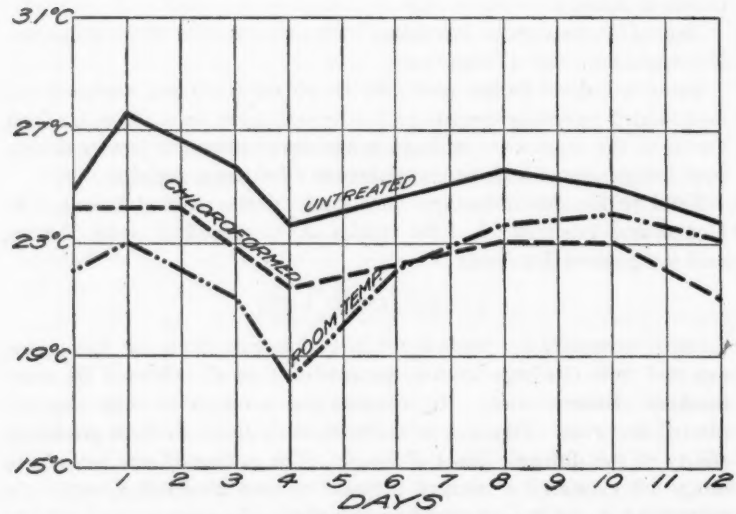

FIG. 2.—Curves representing the heat-producing ability of dry kafir fodder, untreated and treated with chloroform.

forage, that saturated with chloroform and that heated, exhibited no characteristics of silage. The total acidity determinations noted on figures 1, 7, 8, 9, and 10, respectively, indicate the fermentation ability of the various types of forage treated differently.

FIG. 3.—Curves representing the heat-producing ability of dry corn fodder, untreated and treated with chloroform and heat, respectively.

Heat production was only observed in the untreated and inoculated forage. The treated samples offered no indications of heating. The differences noted in the comparative amounts of heat production are probably due to the varying amounts of oxygen incorporated in the jars at the time of siloing the forage.

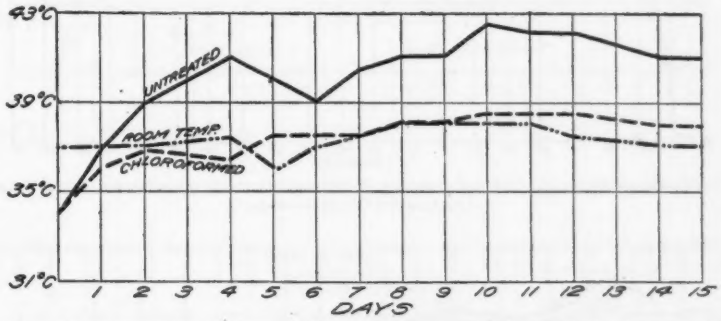

FIG. 4.—Curves representing the heat-producing ability of green cane fodder, untreated and treated with chloroform.

The temperature curve representing the chloroformed forage followed the curve of the heated forage and that of the outside temperature very closely. However, there will be noticed a rapid rise of the treated-forage curves the first few days, which at the first glance might signify heat production. This increase stops at a temperature corresponding

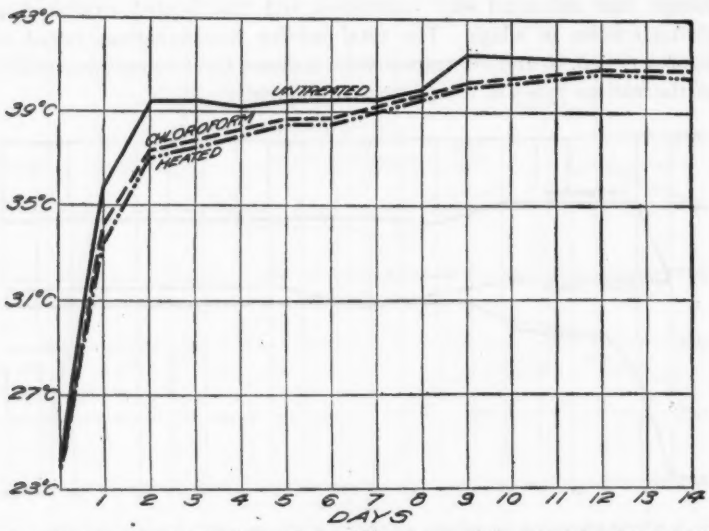

FIG. 5.—Curves representing the heat-producing ability of green alfalfa, untreated and treated with chloroform and heat, respectively.

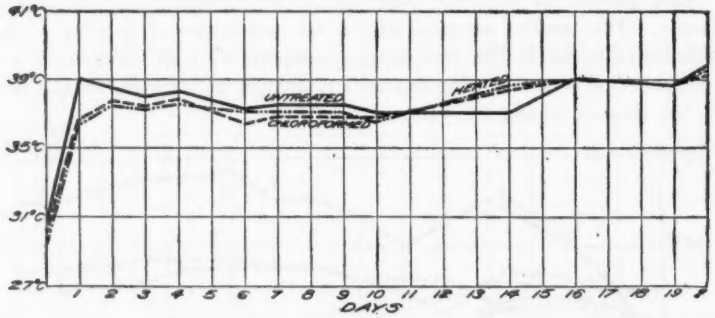

FIG. 6.—Curves representing the heat-producing ability of cured alfalfa, untreated and treated with chloroform and heat, respectively.

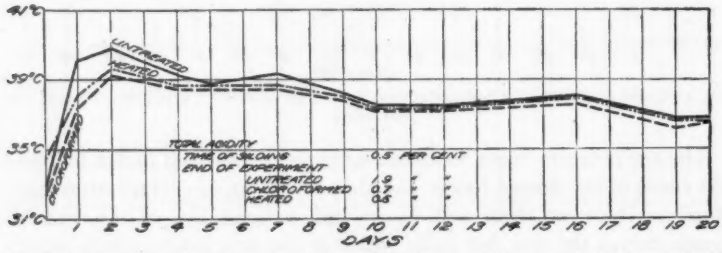

FIG. 7.—Curves representing the heat-producing ability of green alfalfa, untreated and treated with chloroform and heat, respectively.

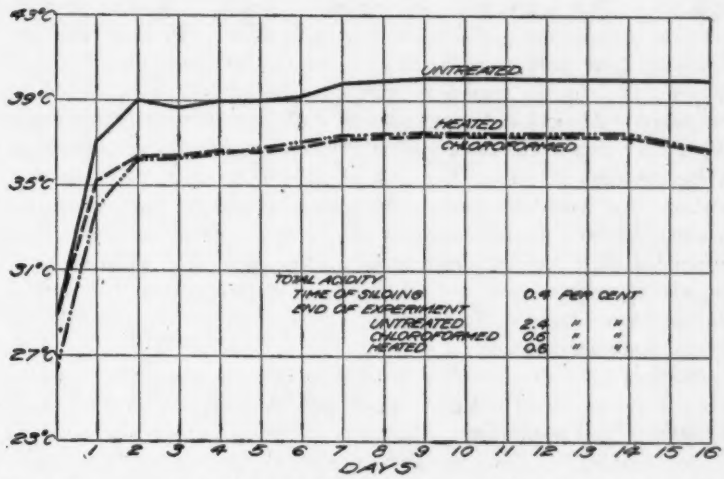

FIG. 8.—Curves representing the heat-producing ability of green corn fodder, untreated and treated with chloroform and heat, respectively.

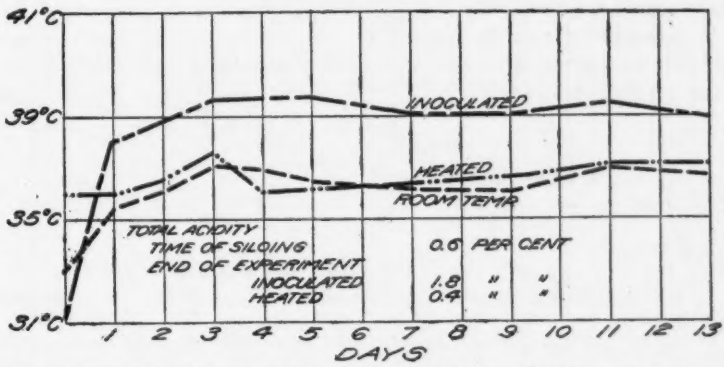

FIG. 9.—Curves representing the heat-producing ability of green kafir inoculated with *Bacterium bulgaricus* and treated with heat.

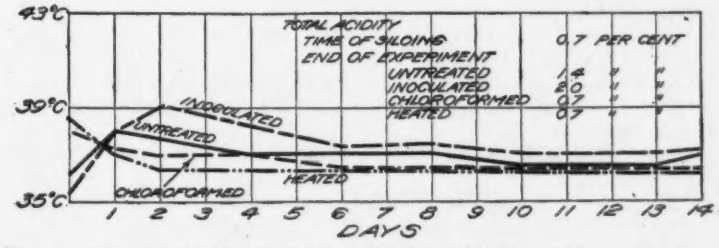

FIG. 10.—Curves representing the heat-producing ability of green kafir, untreated, inoculated, and treated with chloroform and heat, respectively.

with the outside temperature and remains practically the same throughout the experiment. The rise of temperature therefore does not represent heat production in this case, but heat absorption. This is demonstrated by the results in figure 10. Here the temperatures of the untreated and inoculated forage at time of siloing were slightly lower than the temperature of the room (36° to 37° C.) in which the jars were kept, while the temperatures of the treated, chloroformed, and heated were higher. The records in figure 10 indicate a decrease in the temperature readings of both treated samples the first few days, until they corresponded with the temperature outside the jars. The untreated and inoculated samples, however, exhibited heat production, their curves showing a steady rise, exceeding the room temperature and followed by the customary decline.

The fact that dry forage will undergo normal silage fermentation when water is added is significant. Such material can offer no manifestation of cell respiration. However, microorganisms are present and silage is produced. The conclusions are plainly evident.

Temperature curves obtained from the fermentation of dried forage are noted in figures 1, 2, 3, and 6 and are comparable with the fermentation records of green forage.

It is concluded from these investigations that heat production in forage fermentation results from microbial activity and not from intramolecular respiration of the tissue cells.

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ISOLATION OF CYANURIC ACID FROM SOIL

By LOUIS E. WISE and E. H. WALTERS, *Biochemists, Soil-Fertility Investigations, Bureau of Plant Industry, United States Department of Agriculture*

In the course of an investigation of an Indiana soil a nitrogenous compound was isolated and shown to be cyanuric acid (Pl. II). The isolation of this compound was effected in the following manner: Twenty-three kgm. of soil at a time were extracted with about 75 liters of 2 per cent sodium-hydroxid solution at room temperature for 24 hours. The alkaline extract was rendered slightly acid to litmus with sulphuric acid and the acid liquor filtered. The clear acid filtrate was then washed with ether to remove any aldehydes or other soluble acids present, and then treated with an excess of mercuric sulphate in dilute sulphuric acid. The flocculent mercury precipitate was washed by decantation, filtered and washed, suspended in hot water and decomposed with hydrogen sulphid. After the filtration of the mercuric sulphid, the dark-colored filtrate was heated on the steam bath to expel sulphuretted hydrogen, and was then treated with 1 or 2 c. c. of acetic acid. After cooling, this solution was diluted to about 6 liters with water and treated with an excess of a saturated aqueous solution of neutral lead acetate.

The voluminous dark-brown precipitate thus formed was filtered and washed with water. The filtrate was subsequently treated with a large excess of concentrated ammonium hydroxid, and the resulting pale-yellow precipitate was washed by decantation with very dilute ammonia, and finally transferred to a fluted filter paper and washed with water. The moist precipitate was suspended in hot water and decomposed with a rapid stream of hydrogen sulphid.[1] After filtration of the lead sulphid, the straw-colored solution was concentrated to small volume, decolorized with purified boneblack, filtered, evaporated to a brown sirup, and allowed to crystallize. An organic substance then separated, crystallizing in the form of flat plates or small prisms, frequently contaminated with needles of calcium sulphate. The substance was either recrystallized from water or from 50 per cent alcohol, the latter serving to separate it from calcium sulphate. After repeated crystallization from water the compound was obtained in the form of small glassy prisms of varying shapes, which effloresced rapidly when allowed to stand in the air.

The writers were able to establish the identity of the compound obtained from soil with cyanuric acid by carefully comparing its properties with those

[1] A tendency to form colloidal sulphid solutions at this point was sometimes noted. This was overcome by the addition of a few crystals of lead acetate to the solution or by adding small amounts of purified boneblack.

Journal of Agricultural Research, Washington, D. C. Vol. X, No. 2 July 9, 1917 Key No. G—116

of synthetic cyanuric acid prepared by heating urea with zinc chlorid by Von Walther's method (12).[1] Both, when subjected to dry heat, decomposed with the formation of a white sublimate and with the evolution of acid vapors having an odor resembling that of glacial acetic acid. Both synthetic cyanuric acid and the compound isolated from soil yielded similar precipitates when treated with mercuric sulphate, ammoniacal lead acetate, and alkaline barium chlorid. A hot aqueous solution of either the compound from soil or synthetic cyanuric acid, when rendered very slightly alkaline with ammonia and subsequently treated with dilute cupric sulphate, and allowed to cool, yielded a copper salt in the form of characteristic rhombic prisms of a beautiful amethyst color (1, p. 1268). This copper salt, which has the formula $Cu(C_3H_2N_3O_3)_2.2NH_3$, may be obtained from as little as 5 mgm. of cyanuric acid. When very small quantities of cyanuric acid are suspected, the test is best carried out in about 1 c. c. of water in the presence of 3 to 4 drops of concentrated ammonia. Under certain conditions not fully understood the test yields a copper salt which crystallizes in the form of fluffy lilac needles, much paler in color than the rhombic form.

To further establish the identity of the substance obtained from soil, a series of comparative analyses were made, using correspondingly small amounts of the soil compound and synthetic cyanuric acid and their respective salts.

On analysis of the compound obtained from soil:

0.0519 gm. of the compound crystallized from water gave 0.01105 gm. of water of hydration;

0.0215 gm. of the anhydrous compound required 0.01252 gm. of sodium hydroxid for neutralization (phenolphthalein indicator) and yielded 0.00697 gm. of nitrogen.

On analysis of the synthetic cyanuric acid:

0.04485 gm. of the acid crystallized from water yielded 0.00945 gm. of water;

0.0354 gm. of anhydrous acid required 0.01084 gm. of sodium hydroxid for neutralization;

0.0600 gm. of anhydrous acid yielded 0.01953 gm. of nitrogen.

	Water (per cent).
Calculated for $C_3H_3N_3O_3.2H_2O$	21.8
Found in compound isolated from Indiana soil	21.3
Found in synthetic cyanuric acid	21.7

	Neutralization equivalent (molecular weight).	Nitrogen (per cent).
Calculated for $C_3H_3N_3O_3$	129.1	32.6
Found in compound from Indiana soil	130.6	32.4
Found in synthetic cyanuric acid	130.7	32.55

Hot aqueous solutions of both the synthetic cyanuric acid and the compound isolated from soil, when treated with silver nitrate and subsequently with ammonium hydroxid, yielded heavy microcrystalline

[1] Numbers in parentheses refer to "Literature cited," p. 90-91.

precipitates. The compounds thus formed were shown to be identical with a previously described silver-ammonium compound having the formula $Ag_2C_3HN_3O_3.2NH_3$ (1, p. 1268), which when analyzed gave the following results:

Preparation from soil compound:
(a) 0.15295 gm. yielded 0.08900 gm. of silver;
(b) 0.14825 gm. yielded 0.08635 gm. of silver.
Preparation from synthetic cyanuric acid:
(c) 0.2615 gm. yielded 0.1510 gm. of silver;
(d) 0.1335 gm. yielded 0.0778 gm. of silver;
(e) 0.1257 gm. yielded 0.0720 gm. of silver.

	Silver (per cent).
Calculated for $Ag_2C_3HN_3O_3.2NH_3$	57.2
Found in the salt derived from soil compound:	
(a)	58.2
(b)	58.2
Found in salt from synthetic cyanuric acid:	
(c)	57.7
(d)	57.5
(e)	57.3

The largest amount of pure cyanuric acid isolated from one of the 23-kgm. lots of the Indiana soil by the above method was about 0.150 gm. Since the isolation must entail some losses, even this should be taken as a minimal value. This quantity of cyanuric acid represents 6.5 p. p. m. and corresponds approximately to 26 pounds per acre-foot, by assuming the weight of an acre-foot to be 4,000,000 pounds.[1]

It should be mentioned in passing that the properties of cyanuric acid are very similar to those of tetracarbonimid as reported by Scholtz (8) and by Schittenhelm and Wiener (7). By accepting the descriptions of tetracarbonimid given by these workers, both compounds when anhydrous have the same percentage composition, and both give similar precipitates when treated with salts of some of the heavy metals. Both compounds when subjected to dry heat decompose with the formation of a white sublimate and acid vapors. On the other hand, cyanuric acid crystallizes from water with two molecules of water of hydration, whereas no mention is made of water of hydration in the case of tetracarbonimid. Furthermore, the neutralization equivalent, which is essentially a molecular-weight determination, should serve to distinguish between cyanuric acid, which has the formula $C_3H_3N_3O_3$, and tetracarbonimid, which has the formula $C_4H_4N_4O_4$, and the silver-ammonium derivative of cyanuric acid described above has a composition different from that of any theoretically possible silver derivative of tetracarbonimid.

[1] The soil contained 0.0744 per cent of total nitrogen. When extracted with a 2 per cent sodium-hydroxid solution, the soil yielded 56 per cent of the total nitrogen to the alkaline solution. On acidification with sulphuric acid and filtration, only 31 per cent of the total nitrogen was found in the acid solution. When treated with mercuric sulphate in dilute sulphuric acid, the acid solution yielded a precipitate which retained approximately 14 per cent of the nitrogen originally present in the soil. The cyanuric acid isolated corresponds to about 0.30 per cent of the total nitrogen in the soil.

The close similarity in the behavior of tetracarbonimid and cyanuric acid may make the identification of either a difficult matter; and, if the amounts of substance isolated from soil are too small for analysis, it may be impossible to distinguish between the two. In a previous paper (10) from this laboratory the isolation of tetracarbonimid from a number of soils was reported. The compound isolated from one of these soils (a loam soil from the grounds of the Department of Agriculture) was obtained in a quantity too small for analysis. Since then it has been possible to obtain more of this compound from the soil then examined, and the supposed tetracarbonimid has been shown to be cyanuric acid. The analytical data relating to this compound are given below:

0.0564 gm. of the compound required 0.01728 gm. of sodium hydroxid for neutralization and yielded 0.01811 gm. of nitrogen.

	Neutralization equivalent (molecular weight).	Nitrogen (per cent).
Calculated for $C_3H_3N_3O_3$	129.1	32.6
Found	130.6	32.1

The compound from this lawn soil also yielded a rhombic amethyst-colored copper compound similar in all respects to the compound obtained from synthetic cyanuric acid. On analysis:

0.02970 gm. of the copper compound prepared from the substance obtained from this soil gave 0.00660 gm. of cupric oxid.

0.015995 [1] gm. of the copper compound obtained from synthetic cyanuric acid gave 0.003535 gm. of cupric oxid.

	Copper (per cent).
Calculated for $Cu(C_3H_2N_3O_3)_2.2NH_3$	17.96
Found in the copper salt prepared from the compound obtained from the lawn soil	17.75
Found in the copper salt prepared from synthetic cyanuric acid.	17.65

The amount of cyanuric acid isolated from 23 kgm. of lawn soil was approximately 110 mgm. This amount corresponds to about 19.5 pounds per acre-foot.

Cyanuric acid was also isolated from three other soils. A Maine soil yielded about 0.165 gm. of cyanuric acid (sample a) from 46 kgm., a Florida soil yielded approximately 0.040 gm. of cyanuric acid (sample b) from 23 kgm., and a Texas soil yielded about 0.040 gm. of cyanuric acid (sample c) from 46 kgm.

The following analytical data were obtained:

0.059 gm. of crystallized sample (a) gave 0.0124 gm. of water;

0.04785 gm. of anhydrous sample (a) required 0.01458 gm. of sodium hydroxid for neutralization and yielded 0.01575 gm. of nitrogen;

0.0328 gm. of anhydrous sample (b) required 0.010 gm. of sodium hydroxid for neutralization and yielded 0.01060 gm. of nitrogen;

0.0382 gm. of crystallized sample (c) gave 0.0087 gm. of water;

[1] These weighings were performed on an ordinary chemical balance by the method of interpolation as described in text books on physical measurements.

0.0295 gm. of anhydrous sample (c) required 0.009 gm. of sodium hydroxid for neutralization and yielded 0.00969 gm. of nitrogen;

0.03076 gm. of the copper compound derived from sample (a) yielded 0.006765 gm. of cupric oxid.

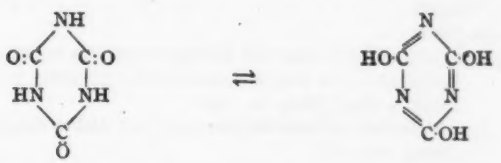
	Water (per cent).
Calculated for $C_3H_3N_3O_3.2H_2O$	21.8
Found in sample (a)	21.0
Found in sample (c)	22.8

	Neutralization equivalent.	Nitrogen (per cent).
Calculated for $C_3H_3N_3O_3$	129.1	32.6
Found in sample (a)	131.3	32.9
Found in sample (b)	128.6	32.3
Found in sample (c)	131.1	32.8

	Copper (per cent).
Calculated for Cu $(C_3H_2N_3O_3)_2.2NH_3$	17.96
Found in copper compound derived from sample (a)	17.6

The soils from which cyanuric acid has been isolated are of widely different origin and type, and it may be expected that the compound or its precursor has a rather wide distribution. The Indiana soil which yielded cyanuric acid belongs to a type which is described (6) as Scottsburg silt loam, light to very light ashy-gray in color, having an average depth of 8 to 10 inches. Fine and very fine sand mixed with the silt gives the soil many of the characteristics of a fine sandy loam. As a type the soil is fairly well drained. The Maine soil used in our work is Caribou loam (13), devoted to potato culture. The soil is underlain at a depth ranging from a few inches to several feet by shale. The drainage is good. The Florida soil above mentioned is chiefly quartz sand and contains very little organic matter. It is devoted to orange culture. The Texas soil, Susquehanna fine sandy loam, is the same soil from which α-crotonic acid has been isolated (11).

Cyanuric acid, which yields two series of isomeric esters (3, p. 181) and mercury salts (4), may be represented by the tautomeric formulas:



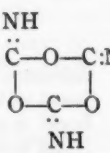
Lactam form. Lactim form.

It is a polymer of cyanic acid, OC:NH.

Cyanuric acid was probably first prepared by Scheele by heating uric acid (2). In 1830 it was synthesized by Serrulas (2) by treating solid cyanogen chlorid with water, and the following year Wöhler prepared it

(2) by heating urea. Wöhler's synthesis of cyanuric acid has been recently modified by Von Walther (12), whose method has been outlined above. Besides these classic methods of preparation, the literature is replete with descriptions of the synthesis of this compound, and mention is frequently made of the occurrence of cyanuric acid as a by-product in reactions involving compounds having the $\diagdown\!\!\diagup C{:}NH$ or $\diagdown\!\!\diagup C.NH_2$ groups.

Cyanuric acid is also formed from its isomer cyamelid,



on prolonged digestion with cold dilute alkali (5). This reaction should be emphasized, since it suggests that cyamelid, if present in the soil, would be converted into cyanuric acid by the method here followed. The isolation of cyanuric acid might even be taken as indicative of the presence of cyamelid, since an alkaline extraction would convert cyamelid into cyanuric acid. Cyamelid may therefore be the precursor of the cyanuric acid isolated in our experiments. Cyamelid is insoluble in all the ordinary organic solvents, and the solvents in which it is soluble (alkali and concentrated acid) convert it into cyanuric acid. It seems impossible therefore to determine whether or not cyamelid is a soil constituent and the mother substance of the cyanuric acid isolated.

Although so frequently referred to in the literature, cyanuric acid has apparently never been previously isolated from a natural source. The above methods of obtaining cyanuric acid suggest the possibility of its formation by the decomposition of nucleoprotein or purin bases, some of which have been previously isolated from soil (9). It is also conceivable that the source of cyanuric acid is urea.

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PLATE 11

Cyanuric acid isolated from Indiana soil. × 120.

FAMILY PERFORMANCE AS A BASIS FOR SELECTION IN SHEEP

By E. G. RITZMAN, *Animal Husbandman, New Hampshire Agricultural Experiment Station*, and C. B. DAVENPORT, *Station for Experimental Evolution, Carnegie Institution of Washington*

Two contrasted methods of selecting mates are in current use. The commonest is that of picking out the best individuals or those that exhibit the traits which are desired in the offspring. This method depends on the principle that the somatic traits of the parent are the best index of its germinal determiners; so that in selecting somatically we are at the same time selecting gametically. This principle is, however, false in so far as the soma is usually a very inadequate index of the germ plasm. In animals that are heterozygous in any trait the germ cells are of two kinds in respect to that trait: (1) those carrying determiners for the trait and (2) those for its absence, or for its allelomorphic trait. Practically it has been found by many breeders of animals and plants that progress is made slowly or not at all by this process.

The other method of selecting mates recognizes the principle that the individual's somatic traits constitute a partial and imperfect index to its germ plasm. A better insight into that germ plasm is gained by considering the traits shown by as many close relatives as possible. Naturally the qualities of the proposed mates are considered, but only as members of their families.

The foregoing principles have been applied in the sheep-breeding experiments at the New Hampshire Experiment Station. The aim of these experiments is to produce a race of sheep that will combine good qualities of conformation, size, and wool. As criteria of these three points we used the following quantities and assigned to each the factor or weight indicated:

SIZE	Weight.
Body weight (pounds)	5
Height at shoulder	5
Chest circumference	5
Loin width	5
Hindleg circumference	5
Total size	25
WOOL	
Weight of fleece	10
Length of staple	10
Diameter of fiber	10
Crimp of wool	10
Total wool	40

CONFORMATION	Weight.
Ratio, head width: length	3
Ratio, neck length: circumference	2
Ratio, foreleg length: trunk length	10
Ratio, chest width: depth	5
Ratio, chest width: trunk length	5
Ratio, loin width: trunk length	5
Ratio, croup length: trunk length	5
Total	35

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July 9, 1917
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The method of selecting by family performance is a natural corollary of the principle that offspring do not "inherit from their parents" but that offspring are derived from some of the same kind of germinal stuff as that from which those parents and their brothers and sisters were derived. And the best knowledge of the varied qualities of the germ plasm is obtained by a comprehensive view of its performance in a number of closely related, fully developed somas. The studies of a score of geneticists (among whom it may not be invidious to mention Pearl, working with the fecundity of poultry) are in agreement upon this point.

Since most of the ewe lambs, but, on the other hand, only a very few ram lambs, are preserved as breeders, the selection of males is the more rigorous. We may illustrate the general method of selection by an example. In the 1916 selection the available ram lambs belonged to 12 "families." A "family" comprised brothers and sisters and the two parents. In selecting the trait "body weight" the average weight of all the members of each family group at a fixed age is calculated. The family having the highest average weight is graded 1; the next highest average is 2; and so on. If the average is the same in two families, they receive the same grading rank; thus, in one selection two males grade No. 4 in body weight and four grade No. 2 in shoulder height. Naturally, one family will grade high in body weight, but low in weight of fleece and perhaps will be medium in ratio of head width to head length. The rank of every family with respect to every quantitative trait is thus determined; the rank is multiplied by its appropriate weight factor as in ordinary scoring. The family which gives the lowest sum of products grades highest, and the best ram from that family (or the better if there be two) is ordinarily chosen. However, if the individual belonging to the "best" family is sickly or has any physiological quality that would interfere with its success as a breeder, the male from the next higher family may be preferred—that is, selection is made primarily on the basis of family performance, but the somatic insufficiency of the individual is permitted to veto the choice based on amily alone. To facilitate such veto, the individual males from which selection is to be made are graded on the basis of their quantitative traits. It is practically found that the best individuals usually come from the families that stand high in the scale. If the representative of the best family should be a ram grading at the bottom of the scale individually, he would probably be rejected and the representative of the second-best family selected. But practically, as stated, the question of relative weight to be given to the individual (as contrasted with family) does not cause much hesitation so long as the principle of selecting permanently on the basis of family is kept in view.

To illustrate the foregoing the procedure in a particular case is given in Tables I and II.

TABLE I.—*Grading of families from which breeding rams are to be selected* [a]

Family No.	1	2	3	4	5	6	7	8	9	10	11	12
Size:												
Body weight, pounds	11	5	7	2	4	8	3	9	6	10	4	1
Height, shoulder	7	1	8	4	2	2	2	6	5	7	3	2
Chest circumference	11	5	8	1	9	7	2	10	4	12	6	3
Loin width	6	3	6	5	8	8	6	7	4	7	1	2
Hindleg circumference	6	8	9	4	7	2	4	3	5	10	4	1
Size totals × 5	205	110	190	80	150	135	85	175	120	230	90	45
Ratio:												
Head width: Head length (3)	6	12	12	6	18	9	3	9	6	12	15	9
Neck length: Neck circumference (2)	16	2	10	8	2	4	8	2	8	12	6	14
Foreleg length: Trunk length (10)	50	20	40	70	90	60	10	80	70	80	30	70
Chest width: Chest depth (5)	20	10	20	5	20	25	15	35	15	30	10	5
Chest width: Trunk length (5)	15	10	15	10	10	10	15	20	10	15	10	5
Loin width: Trunk length (5)	15	15	15	15	20	20	20	15	15	15	10	5
Croup length: Trunk length (5)	30	20	20	15	20	5	30	15	10	25	15	15
Ratio totals	152	89	132	129	180	133	101	176	134	189	96	123
Wool:												
Weight of fleece	11	6	10	2	3	1	2	7	4	9	5	8
Length of staple	9	11	10	1	12	8	7	3	5	4	6	2
Fineness of fiber	4	3	3	3	1	2	1	2	3	2	3	1
Crimp	3	1	8	7	6	5	4	3	4	8	3	2
Wool totals × 10	270	210	310	130	220	160	140	150	160	230	170	130
Grand total	629	409	632	339	550	528	326	501	414	649	356	298
Order of excellence	10	5	11	3	9	8	2	7	6	12	4	1

[a] The number in parenthesis under ratio indicates weight factor by which the grade is multiplied to give product in columns 1 to 12.

Table I shows how families are graded. In this case the first family in order of excellence is No. 12, in which the ram is No. 32. Table II shows that this ram is one of the first two in order of individual excellence. It was accordingly selected as our best sire. The second-best family is No. 7. The ram in this family stands seventh in order of excellence; it was our second choice. The third-best family is No. 4; the ram in this family ranks as the third-best individual; it was chosen as our third-best ram, and so on. The poorest family is No. 10, and the ram from that family is the poorest individual. Ram 64 (family 5) shared first rank with ram 32, but it was not used, despite its very heavy fleece and fine fiber, because the family record for weight of fleece was not extragood, and conformation is very poor.

TABLE II.—*Grading of rams for individual excellence* [a]

Family No.	1	2	3	4	5	6	7	8	9	9	10	11	12
Number of ram	45	28	49	51	64	55	56	58	30	59	60	26	32
Size:													
Body weight, pounds	12	5	11	6	3	8	4	9	2	7	10	4	1
Height, shoulder	10	3	8	6	5	6	4	9	1	9	7	5	2
Chest circumference	13	6	10	7	2	8	3	11	1	9	12	5	4
Loin width	12	3	5	8	4	10	6	11	2	7	9	3	1
Hindleg circumference	8	5	11	7	6	9	2	4	3	10	12	13	1
Size total × 5	275	110	225	170	100	205	95	220	45	210	250	150	45
Ratios:													
Head width: Head length (3)	12	9	15	6	21	12	3	9	18	6	12	24	24
Neck length: Neck circumference (2)	2	22	6	8	20	10	16	18	24	6	4	14	12
Foreleg length: Trunk length (10)	60	80	20	30	10	40	70	40	50	20	60	40	30
Chest width: Chest depth (5)	15	20	25	25	20	30	5	35	15	20	25	25	10
Chest width: trunk length (5)	15	20	10	25	20	15	15	25	10	10	30	25	5
Loin width: Trunk length (5)	30	20	10	25	15	20	25	25	15	15	25	15	5
Croup length: Trunk length (5)	40	35	10	30	20	20	30	25	10	15	10	10	5
Ratio total	174	206	96	149	156	147	234	177	142	92	166	153	91
Wool:													
Weight of fleece	12	10	11	2	1	3	6	8	7	4	10	5	9
Length of staple	2	12	6	1	8	13	7	5	10	4	9	3	11
Fineness of fiber	2	6	5	3	4	1	6	5	7	3	3	6	6
Crimp	1	2	5	6	4	3	3	2	5	3	7	4	3
Wool total × 10	170	300	270	120	170	200	220	200	290	140	290	180	290
Grand total	619	616	591	439	426	552	549	597	477	442	706	483	426
Order of excellence	12	11	9	3	2	8	7	10	5	4	13	6	1

[a] The number in parenthesis under ratio indicates weight factor by which the grade is multiplied to give product in columns 1 to 12.

The system deals not only with relative values. The natural supplement is the real or imaginary "ideal" combining in actual (not relative) degree the traits of the model which we are trying to produce in making our selections. This principle is, of course, also fully recognized by live-stock judges and breeders' associations. With the "ideal" in mind it becomes possible to form a proper estimate of the somatic value of an individual or of a family composite.

In adopting this method of selection an ideal was sought that would combine the desirable traits from each of the two breeds used in our

experiments, Southdown and Rambouillet.[1] These were size and conformation of the former and wool characters of the latter, but intermediateness in thickness of fiber and length of not less than 3 inches. As the Southdown ram 28169 represents an exceptionally desirable type, combined with unusual size for the breed, his measurements were adopted to represent the "ideal" as regards conformation and size.

The ideal score, then, is shown in Table III.

TABLE III.—*The ideal score for size and conformation of rams*

Measures.[a]			Ratios.	
Weight	pounds	200	Head width / Head length	0.68
Height, shoulder	mm.	635		
Head length	mm.	200		
Head width	mm.	135		
Neck length	mm.	285	Neck length / Neck circumference	.60
Neck circumference	mm.	475		
Trunk length	mm.	645	Foreleg length / Trunk length	.59
Chest circumference	mm.	1,100		
Chest depth	mm.	350	Chest width / Chest depth	.86
Chest width	mm.	300		
Loin width	mm.	200	Chest width / Trunk length	.46
Croup length	mm.	180		
Foreleg length	mm.	380	Loin width / Trunk length	.31
Hindleg length	mm.	455		
Hindleg circumference	mm.	485	Croup length / Trunk length	.28

[a] These measurements can all be taken with a simple and inexpensive caliper or with a string.

The results of this method of selection can not yet be given in detail, as the experiment is still in progress. The uniformity of the progeny and the high quality already shown by the earlier generations give us every reason for confidence that this method of selecting by family performance in place of individual traits is well worth the extra trouble it entails, if, indeed, it is not indispensable.

[1] An "ideal" score may, of course, be subject to change. It must be progressive, as animal breeding is progressive.

A NEEDLE BLIGHT OF DOUGLAS FIR

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The fungus described in this paper has been under the writer's observation since 1911. The damage resulting from its activities in forest and nursery since the date of its first discovery has been so great that some mention should be made of it at this time. During the past season (1916) the fungus has been so aggressive in its attacks that strenuous efforts must be made to prevent serious injury to Douglas fir [*Pseudotsuga taxifolia* (Lam.) Britton] in the nurseries. The wide distribution of this fungus in the forests of the Northwest and its destructive effects on young Douglas fir, from seedlings to the 30-year class, have recently become of great concern to foresters. Much material and many letters regarding the disease have been received at the Missoula laboratory from all parts of the Northwest. It is highly instructive to quote from a few of these communications. Mr. J. B. Seely, Forest Supervisor of the Helena National Forest, writes, under date of April 23, 1915:

> The affected timber, *Pseudotsuga taxifolia*, covers an area of several hundred acres in secs. 7, 8, and 9, T. 5 N., R. 5 E., having a northern exposure at an altitude of about 6,500 feet. The affected area is within a pure stand of Douglas fir, and has not increased in any way since first observed nearly two years ago.

Through more recent reports and through observations in this region by the writer, other infected areas have been discovered. Mr. J. B. Lafferty, Forest Supervisor of the Weiser National Forest, Idaho, under date of February 16, 1915, writes:

> Assistant Forest Ranger E. E. McGinnes, in whose district the disease seems to be most prevalent, reports that seedlings and saplings that were badly affected in 1913 died from the effect during the past season; and that the disease is apparently spreading and attacking larger trees.

Mr. John A. Pearson, Forest Supervisor of the Salmon National Forest, Idaho, under date of June 7, 1915, writes that:

> On December last the disease was first noticed on a ridge on the west side of the North Fork of the Salmon River. Since then it has spread to the east side of the river and down both sides for a distance of about 3 miles. The yellow pine does not seem to be affected in any way and very few of the older fir (*Pseudotsuga taxifolia*). Trees from 2 to 20 feet in height seem to suffer most. Some of the trees are nearly bare of foliage, and while it is too early yet to determine whether or not they will die, it seems probable that they will. Infection occurs in spots of from 3 to 20 acres in area, or wherever the reproduction is the best.

A great deal of material was examined from the regions not visited by the writer.

Journal of Agricultural Research,
Washington, D. C.
jb

Vol. X, No. 2
July 9, 1917
Key No. —117

98973°—17—4

The needles of Douglas fir infected with this fungus in early winter develop spots of a slightly yellow color on the under surface, principally at their tips. Each spot represents a single infection and may be very sharply separated from the unaltered green of the uninfected parts of the leaf. Somewhat later the tissues of the leaf on the upper surface directly opposite also turn yellow. By early spring (April and May) these spots have changed to a yellowish brown, and since the uninfected parts of the leaf may remain wholly green, merging into a light-yellow zone next to the area of infection, a peculiar mottled appearance results. About the first of June the needles have assumed, in the case of severe infection, a more uniform brown color, and the entire stand looks as if it had suffered from a severe frost. On the under surface, on either side of the middle nerve of the needle, the spots, now dark brown, begin to round up as small cushions. About the middle of June the epidermis covering these brown areas ruptures with an irregular slit exposing the brownish disk (fig. 1). In cases of severe infection the needles have a very striking appearance (Pl. 12, *A*). At this stage asci in all degrees of development are present (fig. 2). Very frequently, if the tree has been much suppressed by the destruction of its needles through several seasons, mature spores are abundant. By July 1 the asci (fig. 3) are fully mature, and sporulation is active. The liberation of the spores is very greatly promoted by the force of wind and rain on the leaf. When the spores fall on the young needles of the season, which at this period are rapidly growing, it is observed that infection takes places shortly afterwards, provided sufficient moisture is present.

FIG. 1.—Needle of Douglas fir infected with the needle-blight fungus, showing various forms of apothecia and the manner of their rupture.

Snow does not promote the spread of the fungus, as shown by the fact that the needles of the branches of the crown are as badly infected as those lower down. If a wet summer follows the infection, the needles begin to show signs of being diseased before October; otherwise they will remain apparently healthy until December.

The infected needles fall at all seasons of the year, owing to the fact that a portion of them are not as seriously infected as others and may remain on the tree for an indefinite period. A slight jar is often sufficient to cause the needles to fall in a shower. Those that remain longest on the tree after infection produce the apothecia in the spring. In case of a very severe infection, owing to the rapid drying out of the twigs, the needles may remain indefinitely attached, the apothecia becoming black and shrunken. Trees which have been subject to the ravages of the fungus

for several seasons are almost entirely defoliated and either die or merely exist for an indefinite period without making any perceptible growth (Pl. 12, *B*).

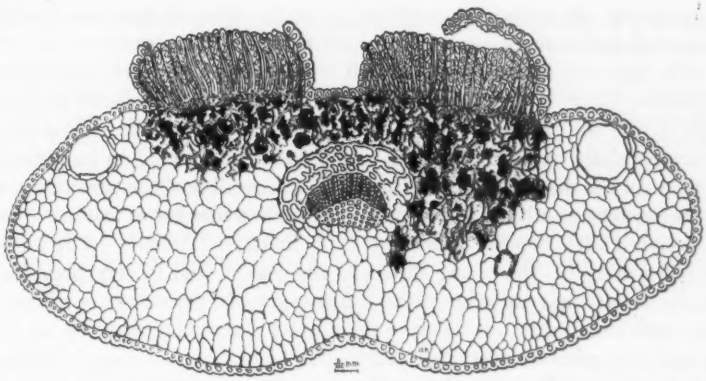

FIG. 2.—Cross section through the middle of two apothecia of the needle-blight fungus, showing the arrangement of the asci and spores, the diseased area of the needle, disorganized cells, and mycelium.

The greatest damage is done in close, pure stands. Since this type of stand is prevalent in many parts of Montana, Idaho, and Washington, the fungus becomes a serious menace to the forest. Repeated observations show that when the fungus becomes once established in dense, even-aged reproduction, none of the ordinary conditions of climate which have been known to arrest other needle diseases seem to prevail against it. It is significant, however, that those trees of the older age classes which are in a close stand and which have escaped the general canopy are, in most cases, free from the disease. Douglas fir in mixed stands is not so frequently attacked.

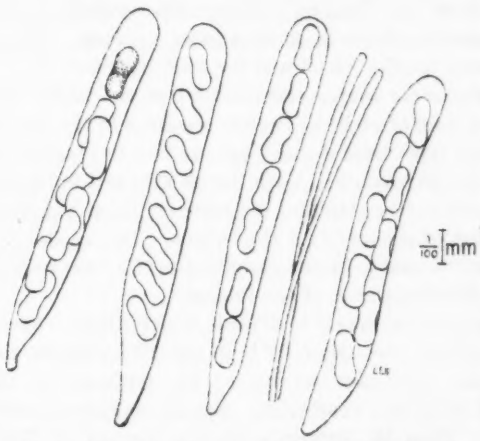

FIG. 3.—Asci with mature spores of the needle-blight fungus on Douglas fir.

The parasitic nature of the fungus is shown by its ability to attack the young needles of the most vigorously growing trees; also by the fact that it does not attack any more rapidly the needles of trees suppressed by mistletoe, root fungi, or insects.

The first evidence that the fungus might cause a serious disease of seedlings in the forest nursery was obtained from a study of all age classes on a south slope in the Bitterroot National Forest, near Missoula, Mont. Practically all reproduction up to 25 or 30 years of age was heavily infected, and in numerous instances the seedlings were dead.

On June 17, 1915, during a visit to the Forest Service nursery at Boulder, Mont. (Helena National Forest), the writer discovered the fungus in the seed beds of 2- to 4-year-old Douglas fir stock. These beds were carefully examined and not one seedling was found to be entirely free from the disease. In most cases all the needles of the previous seasons bore the apothecia of the fungus which in a number of instances was associated with *Botrytis cinerea* Pers. (*B. douglasii* Tubeuf). The latter attacks and kills the young shoots of the season, and is very prevalent in the forests and nurseries of the Northwest.[1] In the denser portions of the beds the fungus was likewise aided in its destructive work by an unusual infestation of what the writer took to be *Chermes cooleyi* Gillette. At the time of the visit the seedlings in the transplant beds were not seriously infected. The pure stands of Douglas fir in the same canyon where the nursery is located were severely infected and exhibited the most serious injury so far observed anywhere in the Northwest. From the observation of field plantings, it is known that Douglas fir seedlings previously infected in the nursery by the fungus under discussion succumb in a very short time. A dozen 3-year-old seedlings infected with the disease were brought from the Boulder nursery and carefully transplanted in the greenhouse at Missoula on December 23, 1914. Before April 26, 1915, the infected needles fell off and the seedlings died. Uninfected seedlings from the same source transplanted at the same time remained healthy. The need of planting healthy seedlings in the field is very apparent. Methods have been devised and are now in practice by which it is hoped this may be realized. A solution of soap and Bordeaux mixture (4–4–50) followed by the standard kerosene emulsion has given indication of being a successful remedy for the fungus. The application of the kerosene emulsion is found to be successful against *Chermes cooleyi*, which greatly aids the destructiveness of the fungus.

The systematic position of the fungus is difficult to determine. Specimens have been referred by the writer both to the Phacidiaceae and Stictidaceae. The former reference was due to the tendency of the hymenium to turn black after long weathering. Specimens have recently been submitted to Mrs. Flora W. Patterson, of the Bureau of Plant Industry, who states—

> We incline toward placing it in Stictidaceae, but find no perfect description in either the old or new genera of any family.

[1] WEIR, J. R. A BOTRYTIS ON CONIFERS IN THE NORTHWEST. *In* Phytopathology, v. 2, no. 5, p. 215. 1912.

In the writer's opinion it plainly belongs in Stictidaceae, a view likewise held by Dr. E. J. Durand, to whom material was submitted. A detailed description of the fungus follows:

Apothecia embedded in the epidermal layer of the substratum, lenticular or oblong-elliptical, scattered, uniseriate, or more frequently biseriate, on under side of needle, sometimes confluent in two rows on each side of the midrib, rarely situated on the middle nerve, usually arranged at the edge of the needle, causing a discoloration of the tissues on the upper side. Epidermal covering of the apothecia rupturing by an irregular longitudinal slit exposing the brownish convex disk, line of rupture more frequently to one side or rupturing from the center in lobes in single or isolated apothecia. Asci cylindrical to clavate (25) 15.7 to 19.4 μ by 113.9 to 153.3 μ (15.7 to 16.5 μ by 125.9 to 129.2 μ), abruptly rounded above, pedicels short, 8-spored, with filiform hyalin paraphyses slightly swollen at tips. Ascospores irregularly biseriate or more frequently obliquely uniseriate, hyalin, 1-celled, oblong, rounded at the ends, rarely obtusely pointed, more frequently constricted in the middle (80) 6.6 to 7.4 μ by 18.2 to 19.8 μ (7.0 to 7.4 μ by 18.2 to 19.4 μ). The pore of the ascus is colored blue by iodin.

SUMMARY

(1) For the past three seasons a needle blight of the Douglas fir has caused great damage to young trees and seedlings in the Northwest. The disease is common both in the nursery and in the forest.

(2) The systematic position of the causal fungus has not been satisfactorily determined, but it is referred for the present to the Stictidaceae. The fungus is vigorously parasitic and is apparently confined to the Douglas fir. It has been found throughout the entire Northwest.

(3) Spraying with a solution of soap and Bordeaux mixture (4–4–50) gives indication of being a successful means of controlling the fungus.

PLATE 12

A.—The needle-blight fungus as it appears normally infecting the 1-year-old needles of *Pseudotsuga taxifolia*. About natural size.

B.—An 18-year-old Douglas fir, showing the thin foliage due to infection with the needle-blight fungus.

A

B